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Status and distribution of an introduced population of European Goldfinches (*Carduelis carduelis*) in the western Great Lakes region of North America

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Abstract

Despite the importance of monitoring introduced species, reports of non-native birds are often initially dismissed by observers. This leads to serious information gaps about source localities, founding numbers, and growth and expansion of potential new populations. Here, we report on European Goldfinches in North America between 2001 and 2021, focusing on the western Great Lakes region. We compiled over 7000 records of European Goldfinches from multiple sources; over 3300 records were from the western Great Lakes. This species was initially reported widely in this region, but over time, birds were most consistently reported between Milwaukee, Wisconsin and Chicago, Illinois. They have been breeding in this area continuously since 2003 and the number of reported observations has increased in recent years. From our compiled records, we describe their distribution, breeding status, nesting phenology, and natural food sources. From import records, we provide evidence that the likely primary founding event of this population was release or escape from a cage bird importer in northern Illinois and provide information on possible origins. We briefly discuss possible ecological impacts. We highlight weaknesses in the way data on non-native species are currently collected and how it has impeded our ability to thoroughly reconstruct the recent history of this species in the western Great Lakes region. Formal study is needed on this population of European Goldfinches, including their potentially increasing population and range, ecology, and an evaluation of the potential effects on native ecosystems.

Keywords

establishment, naturalisation, non-native species, pet trade, release, songbird

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Introduction

Humans have been moving birds from their native ranges to locations around the globe for centuries. Prior to the early 20th century, bird translocations were primarily intentional releases. In particular, an acclimatisation movement peaking in the mid- to late 19th century was coincident with the European diaspora seeking to bring familiar plants and animals to their new homelands for sport or pleasure (Duncan et al. 2003). After that era, introduced birds have largely been the result of accidental releases from the cage bird trade (Blackburn et al. 2010), when there are ample opportunities for release or escape as birds move through the commodity market (Lockwood et al. 2019). The pet trade is now considered the primary conduit for the introduction of non-native birds worldwide (Carrete and Tella 2008; Cassey et al. 2015; Garrett 2018). The current trade volume of songbirds is largely unknown. Gilardi (2006) estimated that 5–10 million birds are taken annually from the wild for the pet trade and many countries have vast domestic markets comprised of hobbyists, larger private aviculturists and commercial breeders (FAO 2011; Lockwood et al. 2019).

There is much we do not know about the dynamics of previous introductions of non-native birds (Blackburn et al. 2015). This may be in part due to the tendency of birders (recreational birdwatchers) to disregard exotic species. Although ornithology has benefited from the efforts of amateurs for many decades, it suffers from a peculiarity of its most avid contributors: a disinterest or even loathing towards non-native species (Pranty and Garrett 2011). In North America, for example, many birders do not consider introduced species as countable on lists they maintain according to rules defined by the American Birding Association (American Birding Association 2020). With the rate of non-native bird introductions rising (Dyer et al. 2017), our ability to manage potential contemporary avian invasions requires increased vigilance and monitoring.

A brief history of European Goldfinch introductions

The efforts of the acclimatisation movement of over a century ago are perhaps best known for the introduction and establishment in many countries of two bird species that developed into serious pests: the House Sparrow (*Passer domesticus*) and European Starling (*Sturnus vulgaris*). Another species was also widely introduced during this period, the European Goldfinch (*Carduelis carduelis*). This attractive member of the Fringillidae is native to Europe, western Asia, and extreme northern Africa. Multiple subspecies are divided into two groups: the western, black-crowned *C. c. carduelis* group of west and central Europe and the eastern, grey-crowned *C. c. caniceps* group of west and central Asia (Cramp and Perrins 1994; Clement et al. 2020).

European Goldfinches were introduced to the Azores around 1860 (Clarke 2006), Australia in 1863 (Acclimatisation Society of Victoria 1863; Ryan 1906), New Zealand in 1864 (Anonymous 1864), Bermuda in 1885 or 1893 (Prentiss 1896; Verrill 1902) and Uruguay in 1913 (Dias 2000). Populations in all these areas persist

today, some of which have spread to nearby islands or countries (Dias 2000; Codesido and Drozd 2021).

The first introduction of European Goldfinches to North America was facilitated by Thomas S. Woodcock (Woodcock 1852). In late 1852, he brought 168 songbirds, amongst them 48 European Goldfinches, to New York City which were held in captivity over the winter (Woodcock 1853). Those that survived, including 16 European Goldfinches, were released on 20 April 1853 in Green-Wood Cemetery in Brooklyn (Woodcock 1853; Cleaveland 1866). None of the released birds was seen past late summer (Cleaveland 1866). The species first appeared in New York City's Central Park in 1879 (Adney 1886) purportedly having crossed the Hudson River from Hoboken, New Jersey, where birds were said to have been released the previous year (Eaton 1914; Cruickshank 1942 Austin 1963). European Goldfinches were later reported as common in parts of New York City, with a maximum report of 50 in winter 1902 (Abbott 1902). Griscom (1923) wrote that they were gone from Central Park by 1907 and that very few were reported anywhere in the New York City area by the early 1920s. They did continue to be reported from Long Island in Nassau County, New York (Nichols 1936; Lincoln 1998). The highest numbers published for that area were 17 in 1938 (Eynon 1940) and ~ 24 in the mid-1940s (Lincoln 1998). The population there persisted until the 1950s when they disappeared due to habitat changes related to development (Elliott 1968). European Goldfinches were also reported as common in eastern Massachusetts by 1880 (Brewer 1879; Allen 1880), but apparently never achieved a self-sustaining population (Brewster 1906; Strohbach et al. 2014).

Elsewhere in North America, a temporarily successful introduction occurred in Oregon, where 40 or more pairs were introduced around Portland in 1889, 1892 and 1907 (Anthony 1891; Pfluger 1896); they thrived for some years, but did not persist (Jewett and Gabrielson 1929). Unsuccessful attempts to establish European Goldfinches in North America occurred in St. Louis, Missouri in 1870 (Widmann 1907); Cincinnati, Ohio in 1872–1874 (Langdon 1881); and Vancouver, British Columbia in 1908 or 1910 (Carl and Guiguet 1972).

Over the latter half of the 20th century, scattered European Goldfinch sightings in North America were considered released or escaped birds. In the western Great Lakes region, Wisconsin had four published records prior to the 1990s (Jung 1936; Lound and Lound 1956; Frank 2004). In Illinois, up to seven European Goldfinches were reported in September 1953 in Chicago's Lincoln Park, Cook County, including adults and dependent young (Binford 1993). These furnished the first Illinois records (contra Smith and Parmalee 1955).

Around 2001, sightings of European Goldfinches in the western Great Lakes region of the United States began to increase beyond occasional reports, a situation suspected at the time to originate from a cage bird dealer in Illinois (Dinsmore and Silcock 2004). Craves (2008) compiled records through mid-2006 from this region, revealing nest building activity in 2003 and successful fledging of young in 2005. In the decades since, European Goldfinch reports have continued to increase, but a full treatment of their status is lacking.

Here, we compile occurrence records of European Goldfinches from 2001–2021 to describe their: 1) distribution, 2) breeding status and phenology, 3) natural food sources and 4) apparent introduction pathway. We also briefly discuss their potential ecological impacts. Our intent is to summarise the early phase of establishment and to prompt formal study of this species in North America.

Methods

To assess the recent distribution of European Goldfinches in North America and their breeding status in the western Great Lakes region, we assembled a database of European Goldfinch occurrences for the years 2001–2021, inclusive, for the United States and Canada. We compiled this dataset of observations from three citizen science projects: eBird (https://ebird.org), Project FeederWatch (https://feederwatch.org) and iNaturalist (https://www.inaturalist.org); a search of the grey literature; a review of online websites including social media and the photo sharing site Flickr (https://www.flickr.com); and observations received directly by JAC that were solicited for an earlier publication (Craves 2008).

eBird is a database of observations contributed by bird watchers, launched in November 2002 (Sullivan et al. 2009). We downloaded the eBird Basic Dataset (eBird 2022) which contains all records marked as approved for public output because they passed through a local checklist filter or were manually approved by volunteer regional reviewers. In some localities, European Goldfinch sightings were not approved and made public by eBird reviewers due to their introduced status; we requested these additional records. Recognising that many bird watchers do not consider introduced species as countable on lists they maintain according to rules defined by the American Birding Association (American Birding Association 2020), we also requested records input in ways that prevent exotic species from appearing on eBird lists, such as entering the record as a less precise taxon (for example, as finch sp. or goldfinch sp.) or using a count of zero. We included records which noted the observation referred to European Goldfinch in any of the comment fields.

On iNaturalist, started in 2008, contributors submit observations (primarily photos) of any taxa and propose or request an identification, which can then be verified by the community (Di Cecco et al. 2021). Project FeederWatch collects observations at feeding stations by participants across North America from November through April; the first winter using the current protocol was 1987–88 (Bonter and Greig 2021). We extracted European Goldfinch records from these sources.

Records received by JAC were solicited beginning in mid-2003 on social media, online listservs and the (now defunct) website of the Rouge River Bird Observatory. The request was specifically for records from January 2002 through August 2006 from the U.S. Midwest and north-eastern States. Reports from other States and dates were also received and retained. Nearly all records were from backyard birders who saw and/or photographed European Goldfinch(es) at their bird feeders, searched online for

the identification of this unfamiliar yet distinctive species, and found the request for information. After the publication of Craves (2008), JAC continued to receive reports, albeit in decreasing numbers, and they are included in the dataset.

We screened all records for accuracy, including any associated media. Duplicate records between data sources were removed, retaining the record containing the most data. We also removed all but one in a group of identical eBird checklists that were shared amongst multiple observers, but did not attempt to identify or remove records of what may have been the same bird at the same place submitted by different observers. Each resulting record is an observation of ≥ 1 European Goldfinch(es) at a particular time and place. Although we have confidence in the overall accuracy of the dataset for describing occurrence and range, the mixed unstructured and semi-structured nature of the dataset and the often incidental and sometimes duplicate nature of the observations make it difficult to conduct rigorous estimates of abundance.

From this continent-wide dataset, we delineated the western Great Lakes region as the area between 51° and 37.5° latitude and -96° and -81°longitude. This included all observations from the U.S. States of Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Kentucky, and Ohio, and adjacent parts of the Canadian Province of Ontario. To explore possible increases in population, we used simple linear regression to test for a relationship between mean count of birds per record (a metric that may be less subject to the sampling bias in our dataset) and year using R version 4.1.0 (R Core Team 2021).

To assess breeding status, we reviewed all records within the western Great Lakes region from March through August. We applied standardised breeding evidence codes used by eBird (eBird 2021), which are adapted from codes utilised by North American breeding bird atlas projects (Beck et al. 2018). These codes are grouped in categories, based on the strength of evidence, from merely Observed, to Possible, Probable, and Confirmed. We focused on the higher-level categories of Probable and Confirmed. The eBird dataset included records from Wisconsin's second Breeding Bird Atlas for the years 2015–2019, so these years have more even geographical coverage and precise estimates of breeding for that state. We summarised breeding records to the highest breeding category and plotted them within U.S. Geological Survey 7.5-minute quadrangles, a standard basis for most North American breeding bird atlases. We also plotted breeding codes by day of year to investigate breeding phenology.

To characterise natural food sources, we reviewed associated media from all records in eastern North America to record as many potential food plants as possible that are likely to occur in the western Great Lakes region. We identified plant taxa to species when possible.

To identify possible pathways of introduction for European Goldfinches to the United States, we obtained import data from the U.S. Fish and Wildlife Service's (USFWS) Law Enforcement Management Information System (LEMIS) database. These data come from declaration forms submitted to the USFWS for all incoming shipments of wildlife, self-reported by the importer with data generally not verified by USFWS (Smith et al. 2017; Eskew et al. 2020). The LEMIS data are only held by USFWS for 5

years and must be obtained by a Freedom of Information Act request. We obtained the available archived data for the years 2000–2014 maintained by the EcoHealth Allliance (Eskew et al. 2019; Eskew et al. 2020) by using the 'lemis' package (Ross et al. 2019) in R (R Core Team 2021) to query the LEMIS Wildlife Trade Database.

Results

Distribution

We compiled 7120 records of European Goldfinches across North America from 2001–2021 (Fig. 1). Observations were recorded in 41 U.S. States and nine Canadian Provinces (Suppl. material 1). The eastern, grey-crowned *C. c. caniceps* race made up < 1% of the entire dataset. The majority of records were from eBird (82%) and those directly received by JAC (9%). The bulk of the eBird records (88%) were accumulated from 2015–2021, while most of the directly reported records (71%) were from 2001–2006.

Forty-seven percent of all records were from the western Great Lakes region and the majority of those (n = 2919) were from Illinois and Wisconsin (Fig. 2). Similar to the overall dataset, 90% of the records for this region were from eBird and those directly received by JAC. The bulk of the eBird records (90%) were accumulated from 2015–2021, while most of the directly reported records (74%) were from 2001–2006. Of the 2467 eBird records for the western Great Lakes region, 80% were "complete" checklists, in which the users indicated they recorded all species they were able to identify. Ninety-four percent of these complete checklists were from 2015–2021. About 40% of all records from the western Great Lakes region were from the last week in March through May. Only about 4% of records were from mid-August through October.

The general pattern of records for the years 2007–2014 for both the overall dataset and the western Great Lakes region was a decreasing number of directly reported records and records in the grey literature and an increasing number of eBird records.

Initial records were loosely clustered in north-eastern Illinois and south-eastern Wisconsin with scattered outliers in neighbouring States. From 2004–2006, there were records across the entire region, after which outlying records declined, but continued in the vicinity of the original cluster (Fig. 3). Since about 2018, records were concentrated between the cities of Milwaukee, Wisconsin and Chicago, Illinois and mostly within 15 km of Lake Michigan.

In the western Great Lakes region, every year in our time range had records with counts of at least two birds. Beginning in 2009, each year had records reporting counts of five birds. From 2013 on, each year had counts of at least 10 birds. Starting in 2016, each year had records of 20 or more birds. All counts of European Goldfinch ≥ 20 individuals were in Illinois or Wisconsin and nearly all were in winter (November through February). There are six records of ≥ 50 European Goldfinches with the highest single count being 95 on 1 January 2021 in Lake County, Illinois. There was a significant increase from 2001 to 2021 in the mean count of birds per record (0.12 ± 0.02 [SE]; $R^2 = 0.64$, $t = 5.8$, $df = 19$, $P \leq 0.001$). The mean number of European Goldfinches per record in 2021 was 3.6.

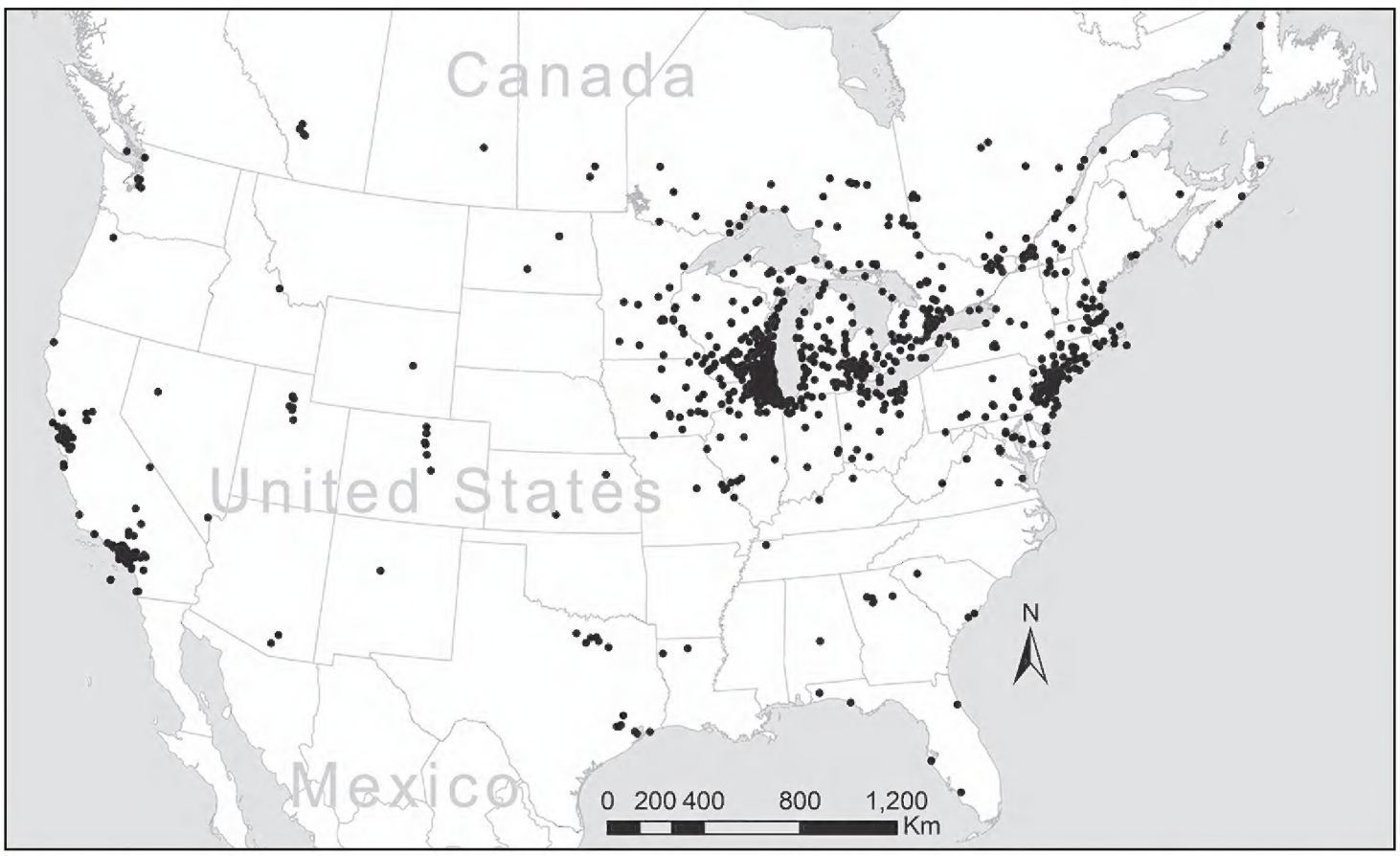

Figure 1. Locations of records of European Goldfinches in North America, 2001–2021. A table of the number of records by U.S. State and Canadian Province with county totals is in Suppl. material 1.

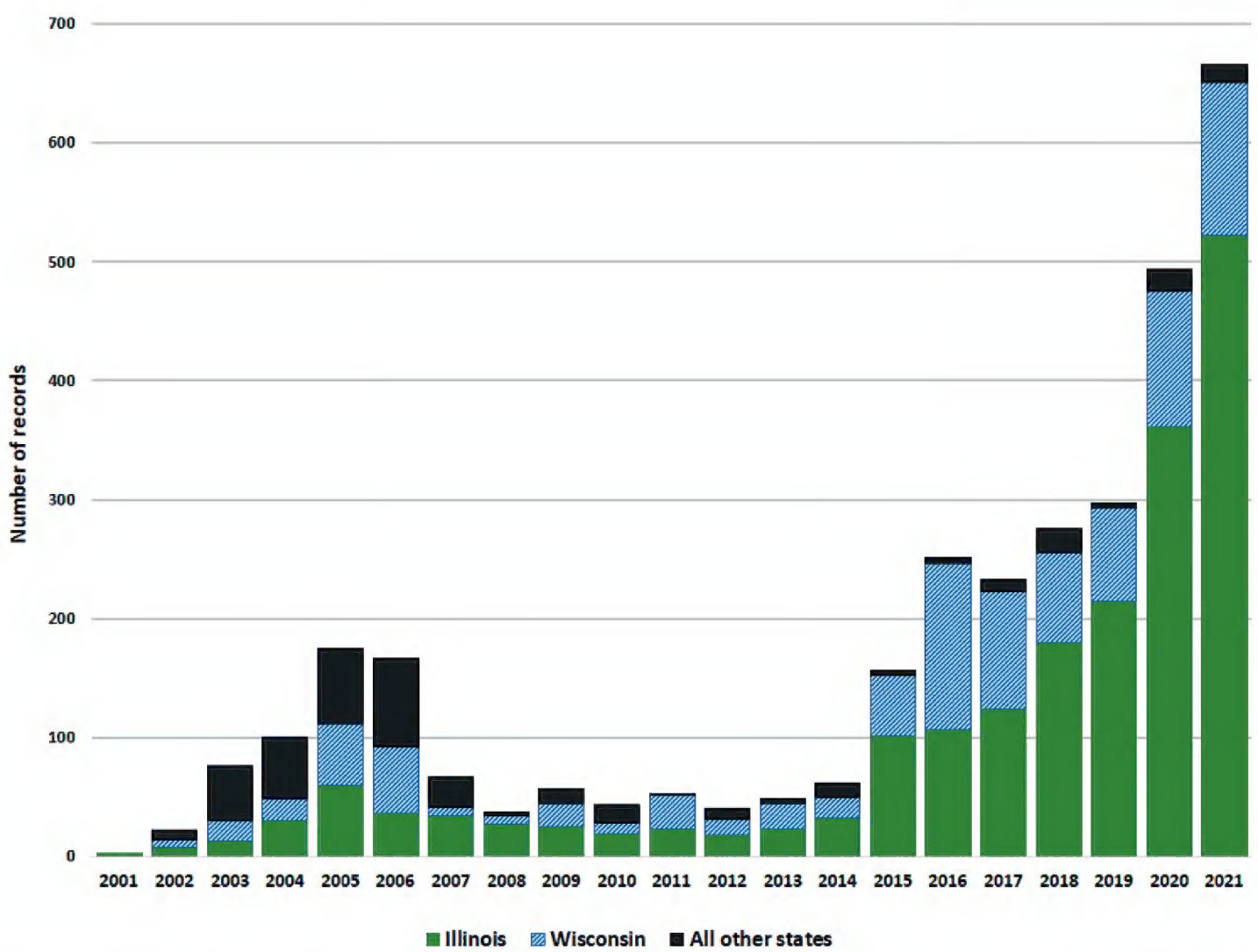

Figure 2. Number of records of European Goldfinches in the western Great Lakes region, 2001–2021. Stacked bars show proportions from the core population in Illinois and Wisconsin, and all other States (Minnesota, Iowa, Missouri, Indiana, Kentucky, Michigan, Ohio, and Ontario west of -81°longitude).

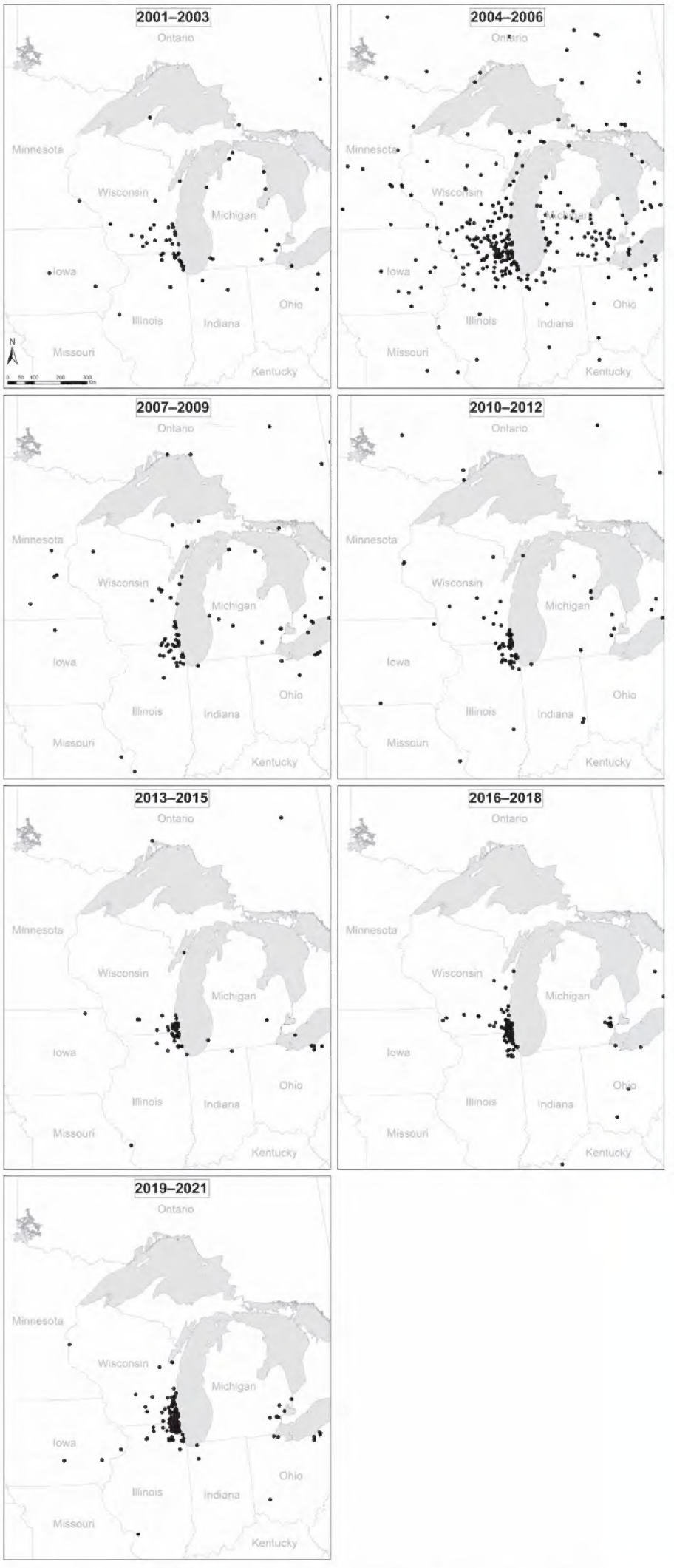

Figure 3. Records of European Goldfinches in the western Great Lakes region grouped in 3-year increments. Some points in these panels are outside our geographic boundaries of this region due to map projection distortions. An animated depiction of the accumulating records over time can be viewed at https://tinyurl.com/bdz8vxt3.

Breeding status and nesting ecology in the western Great Lakes region

We assigned breeding evidence codes for 2320 records in the western Great Lakes region from the months of March through August. Nineteen percent of these records were from March, 26% from April and 28% from May. The number of records decreased over the rest of the breeding period, with 12% in June and the remainder in July and August. The majority of these records were assigned codes in the Observed or Possible categories and, therefore, did not provide strong evidence of breeding (eBird 2021). The remainder (n = 274) were coded in the Probable or Confirmed categories. None of these birds was noted as *C. c. caniceps* either by the observer or in our review of media.

The majority (n = 268) of Probable or Confirmed records were located in northeast Illinois and southeast Wisconsin (Fig. 4). There was a single breeding record in the State of Ohio that falls outside the extent of Fig. 4: a pair of goldfinches frequented a feeder in Cuyahoga County in 2015, where an adult and immature were photo-

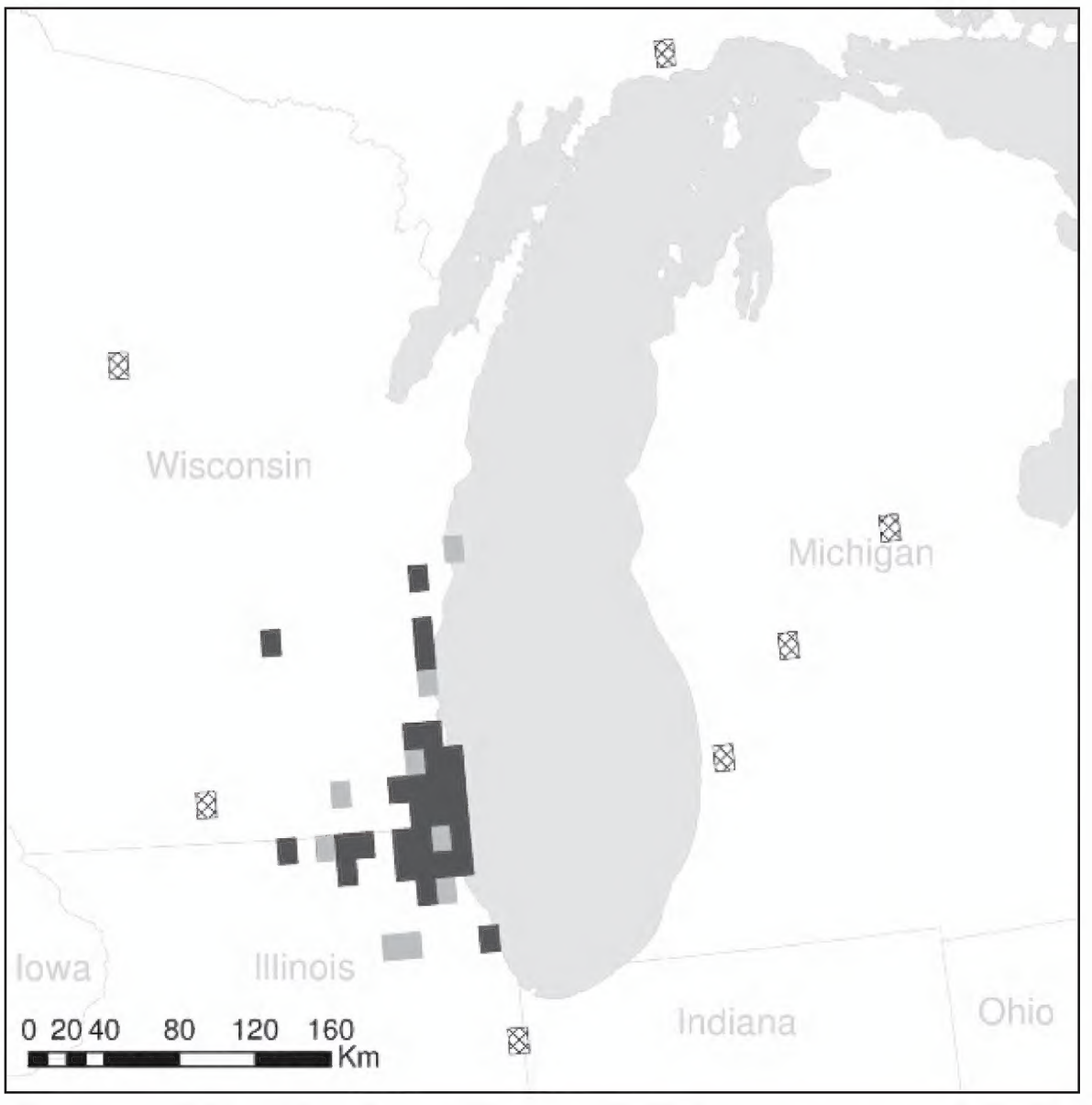

Figure 4. Locations with breeding evidence of European Goldfinches in the western Great Lakes region. From records categorised as Probable or Confirmed, the highest breeding evidence is plotted in USGS 7.5-minute quadrangles. Black represents Confirmed, grey represents Probable, crosshatched represents European Goldfinch pairs (Probable) recorded in 2006 in quads where no records of multiple birds occurred in later years. Quads may contain multiple breeding locations and some quads overlap county lines. A confirmed breeding record in Ohio is outside the map boundaries and not shown (see Results).

graphed on 22 August 2015. We plotted seven Probable records coded P (Pair in Suitable Habitat) from 2006 separately in Fig. 4; although pairs were initially present in these quadrangles, no breeding confirmations were ever reported in these areas and no records of multiple birds occurred in years after the initial reports. They are not included in the totals below.

Illinois had 155 records with high-level breeding evidence. European Goldfinches were confirmed in 13 quads in four counties and coded as probable in five additional quads and two more counties. The majority of the records (n = 141) were from Lake County. Breeding evidence, a pair constructing a nest, was first reported in the State in 2003, there have been Probable and/or Confirmed records in the State every year since.

In Wisconsin, there were 113 records coded Probable or Confirmed. European Goldfinches were confirmed breeding in 16 quads in seven counties. They were coded as probable in four additional quads. Most records were from Racine County (n = 62) and neighbouring Kenosha County (n = 33). Breeding evidence was first reported in Wisconsin in 2004 and there have been Probable and/or Confirmed records in the State every year since 2009. A link to a map file showing the Confirmed records with county boundaries is in the Suppl. material 2.

Records showed that nest building was initiated as early as 1 March, with nest building activities extending to 27 July (Fig. 5). Occupied nests were reported from 13 May though 8 July, and fledged young were reported from 22 May through 30 August (Fig. 5).

Natural food sources

Our examination of media associated with European Goldfinch records resulted in 125 observations of European Goldfinches utilising natural food sources in eastern North America. We identified all plants to at least genus (Suppl. material 3, which provides scientific names) and all 16 plant taxa occur in the western Great Lakes region (USDA NRCS 2022). Ten non-native plant taxa, all of Eurasian origin, made up 80% of the observations. The remaining six plant taxa are native to North America, but represent species or genera that have been introduced from North America into at least parts of the native range of European Goldfinches (Royal Botanical Gardens Kew 2022). Most observations (89%) and most plant taxa (69%) were herbaceous plants and the rest were trees. All observations were of European Goldfinches eating seeds, except for a video of a bird eating the flower buds of a bigtooth aspen tree.

Potential introduction pathway

Import data from LEMIS indicate that nearly 159,000 European Goldfinches were imported into the U.S. for the purpose of commercial trade from 2000–2014. This number is conservative, as it does not include potential European Goldfinches which may have been amongst the > 16,000 birds listed under *Carduelis* sp. or the thousands of birds listed under even more generic terms. The country of origin of most birds,

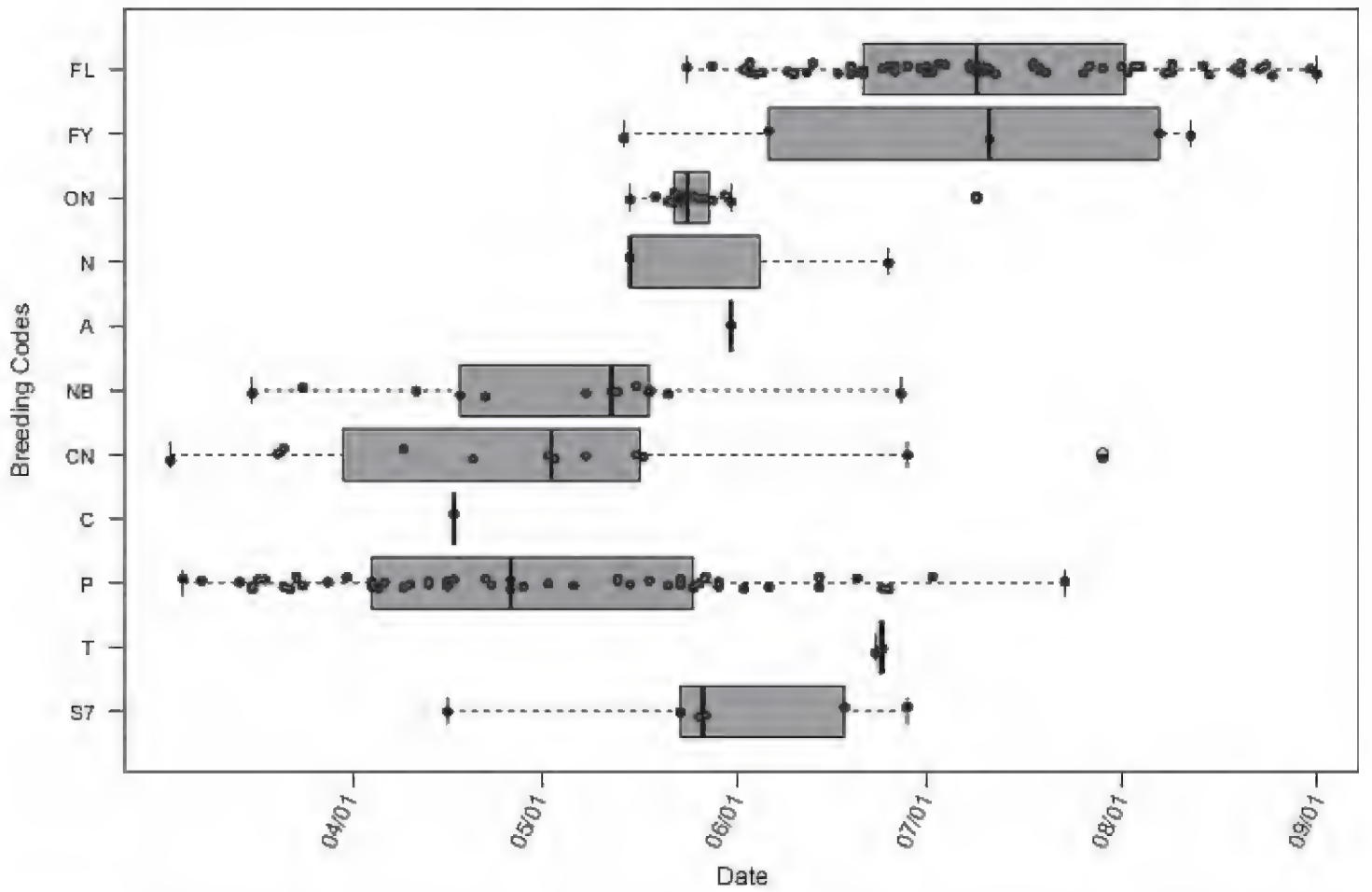

Figure 5. Phenology of breeding activities of European Goldfinches in the western Great Lakes region. Black vertical lines represent median dates. Boxes represent 1st and 3rd quartiles. Whiskers represents minimum and maximum dates, with solitary dots representing outliers. Breeding codes are as follows: FL (Recently Fledged Young), FY (Feeding Young), ON (Occupied Nest), N (Visiting Probable Nest Site), A (Agitated Behaviour), NB (Nest Building), CN (Carrying Nesting Material, C (Courtship Display or Copulation), P (Pair in Suitable Habitat), T (Territorial Defence), S7 (Singing Bird Present 7+ Days). Full definitions and application of these codes can be found at eBird (2021).

60%, was given as Australia, all of which were coded as captive-bred. Another 34% were from Russia, of which 67% were coded as captive-bred and the rest having been taken from the wild (Fig. 6).

Over 99% of the European Goldfinches were imported by three entities. The largest quantity, 39%, was imported by a company headquartered in McHenry County (Illinois Secretary of State 2022). This company was the sole importer of the European Goldfinches from Russia, receiving > 53,000, all in the years prior to 2006. From 2008–2013, the Illinois company received ~ 6100 wild-caught birds from Uzbekistan and 50 captive-bred birds from the same country in 2014. They also received a small number, < 3% of their total imports, of captive-bred birds from Spain ≥ 2005.

Another 30% of the total were imported by a California company which acted as the sales office of the Illinois company (California Secretary of State 2022; Moody's Analytics 2022), all were from Australia. A second California company received 30% of total imports, which were also all from Australia, with the exception of 500 captive-bred birds from New Zealand.

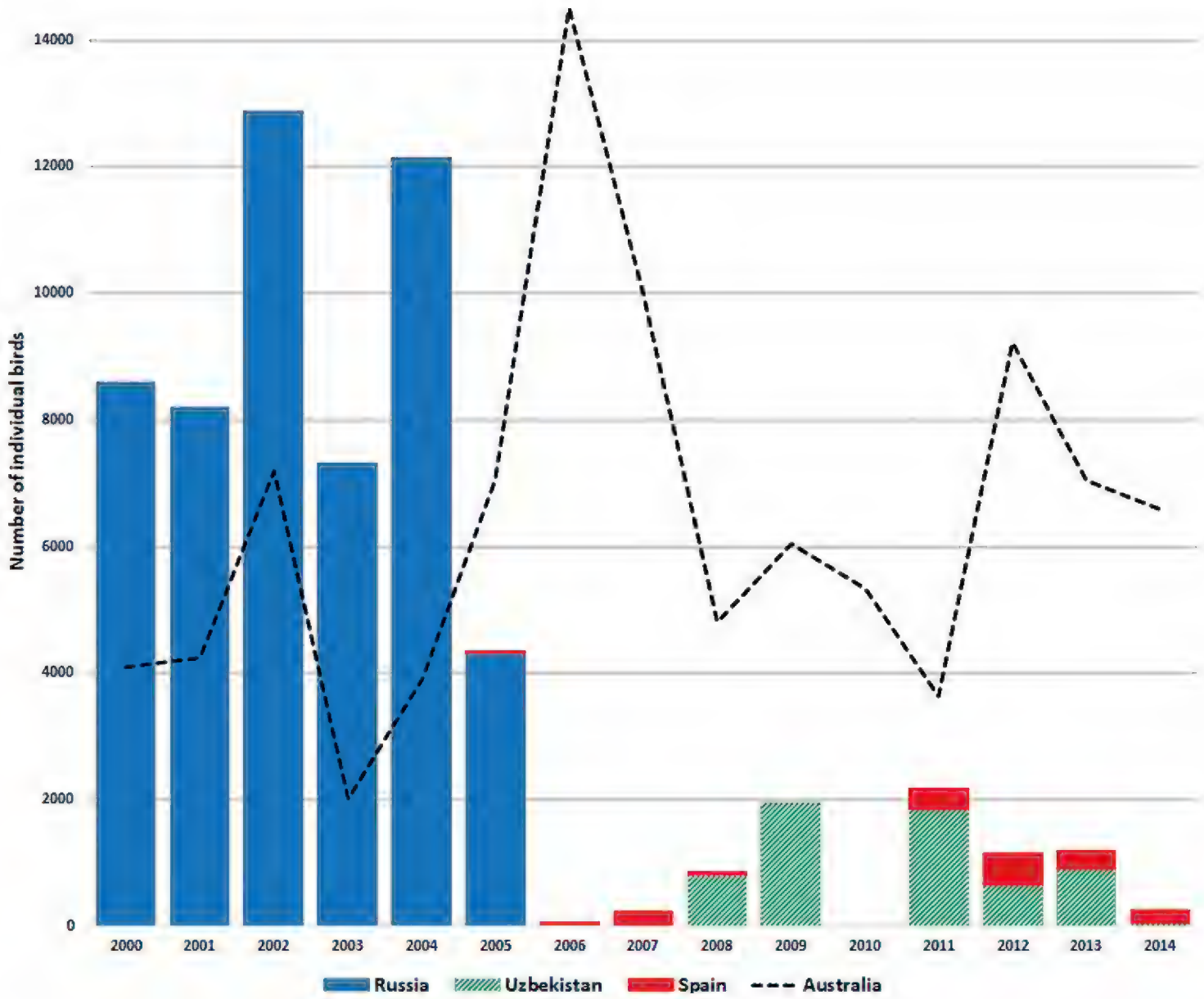

Figure 6. Country of origin and number of European Goldfinches imported into the United States for the purpose of commercial trade, 2000–2014 (all available data). Dashed line represents birds imported from Australia by two California companies. Bars represent birds imported by a single Illinois company. Not shown are < 1700 birds imported from Canada, China, and New Zealand by four other entities.

Discussion

Our compilation of occurrence records of European Goldfinch in North America was derived primarily from two sources: directly reported records solicited primarily from the Great Lakes region, mostly covering the period through mid-2006; and eBird records, submitted under various protocols which were mostly accumulated from 2015 through 2021. Although all sources contributed records to most years, the early years of our study were dominated by presence-only records with no effort metrics, submitted by casual birders, often from residential feeders. The later years were characterised by increasing numbers of eBird records, some of which were complete checklists and/or included effort metrics, that were concentrated in popular birding locations. Each of these opportunistic, unstructured, or semi-structured sources has shortcomings, but the accounting of European Goldfinches over the past two decades would be incomplete and misleading without considering them as a whole. Although the extreme heterogeneity and biases of the available data did not allow for robust population or

spatial analyses, the sheer number of records merits attention and cannot be dismissed as simply an amalgamation of escaped pets.

We believe the > 7,000 records in our dataset to be conservative due to the strong bias by birders against reporting introduced bird species. Two-thirds of birders who keep lists of species they observe do not include "uncountable" exotic species (Callaghan 2017). Most of our records came from eBird, where 90% of checklists are submitted from the most active 10% of users (Wood et al. 2011). Active participants are those who tend to be motivated by achievements, such as keeping a life list (Rosenblatt et al. 2022). Although eBird has encouraged users to enter introduced species, it has been estimated that 36% of eBird users only input those that are countable and 11% do not report them at all (Callaghan and Brooks 2020).

The second-most common source of records were reports from people responding to requests for information made online, which limited replies to those active online. Similarly, we obtained European Goldfinch records from many other online sources. Due to the large number of these types of sites, their variable membership or privacy settings, and their often-ephemeral nature, this search was not exhaustive and undoubtedly some records were missed.

Distribution

The initial increase in reports of European Goldfinches in the western Great Lakes region began around 2002. This was followed by a large increase in the number of European Goldfinch and other non-native cage bird records in the Great Lakes region over the years 2004–2006 (Fig. 2, David 2005; Craves 2008). At that time, it was rumoured that an Illinois dealer (the same one we identified through import records) was either purposely releasing birds or had lax husbandry practices (Dinsmore and Silcock 2004; Fiske 2004). We believe a global outbreak of pathogenic avian influenza H5N1 may have also played role. The outbreak originated in Asia in late 2003 and wild migratory birds were implicated in its spread (Gauthier-Clerc et al. 2007). In 2005, there was a total embargo imposed on imports of birds from Russia (HHS/CDC 2006), the source of nearly all European Goldfinches imported by the Illinois company up to that point (Fig. 6). We speculate that a substantial number of European Goldfinches and other species may have been released by the Illinois company during this period due to concerns about captive birds having, getting, or transmitting avian influenza; the potential need for additional inspections or health screening; and/or possible restrictions on sales (Gilardi 2005; Senni 2005; Romagosa 2015).

Reports diminished between 2007 and 2014. This may have been due to the discontinuation of solicited records by JAC in 2006, or an actual decline in the number of birds in the region. Beginning in 2006, the number of European Goldfinches imported by the Illinois company was also greatly reduced because of the import embargoes, from a mean of around 8900 birds annually prior to 2006 to fewer than 900 a year thereafter (Fig. 6). If the Illinois company was the source of the European Goldfinches in the region, perhaps the reduced inventory resulted in fewer releases or escapes.

Beginning in 2015, the number of reported observations began to increase substantially in the western Great Lakes region, mostly in Illinois and Wisconsin. In part, this may be attributed to the rising usage of eBird, including the debut of their mobile app (Team eBird 2015). European Goldfinch records were also approved for public display on eBird maps in some parts of Wisconsin and Illinois around this time, thus increasing awareness. Additionally, participants in the Wisconsin Breeding Bird Atlas were specifically instructed to watch for the species and report them via the eBird atlas portal (Anich and Craves 2015).

The steady increase in reports may also reflect the start of a period of population growth after an initial lag phase (Crooks 2005; Aagaard and Lockwood 2014), similar to the pattern that occurred after the introduction of the House Finch (*Haemorhous mexicanus*) into eastern North America ~ 1940. After a ban on the sale of these protected migratory birds, native to western North America, at least one New York area dealer apparently released their stock (Elliott and Arbib 1953). The founding population was estimated at 80 birds (Veit and Lewis 1996). The eastern population of House Finches was estimated at 280 birds in 1951 (Elliott and Arbib 1953). Numbers increased 10-fold from 1962–1971, coincident with rapid range expansion (Bock and Lepthien 1976; Veit and Lewis 1996).

The distribution of European Goldfinch records from 2001–2006 (Fig. 3), appears to show widespread dispersal from north-eastern Illinois and south-eastern Wisconsin, a pattern that supports our theory of a substantial release of birds around 2005 originating in that area. The reduction in records and apparent geographic contraction that followed may represent the failure of scattered individuals to establish satellite populations away from the northern Illinois source. There is a possibility that the observed pattern might also be influenced by the increasing number of eBird records which are concentrated closer to population centres and popular birding sites and the discontinuation of solicited records, many of which came from more rural counties that have less eBird coverage.

Breeding status and nesting ecology in the western Great Lakes region

With well over a decade of continuous breeding in Illinois and Wisconsin, it appears that European Goldfinches are establishing a self-sustaining population in this area. Our data indicate the nesting ecology of European Goldfinches in the western Great Lakes region is similar in many respects to those of previous North American populations as well as in the native range.

Cruickshank (1942) gave egg dates ranging from 26 April to 4 June for birds in the New York region. Our records of nest construction activities in March suggest a slightly earlier commencement of breeding, perhaps due to an advancement in egg laying over the ensuing decades. This has occurred in Britain, where the mean laying date of European Goldfinches moved up 20 days over the period 1968–2019 (Walker et al. 2020).

Cruickshank (1942) and Elliott (1968) reported several nests being built or with eggs in July. From this, Cruickshank concluded European Goldfinches were single-brooded, while Elliott felt these late nests indicated double-brooding. We had just two

records of nests being constructed or occupied after late June in our dataset. Given that only 26% of our breeding season records were from June–August, we hesitate to draw any conclusions on how many broods are attempted by European Goldfinches annually in the western Great Lakes region.

Natural food sources

Various methods have been used to study the diets of wild European Goldfinches or granivorous passerines, including prolonged field observations, gut flushing, and post-mortem stomach content analysis (Middleton 1970; Campbell 1972; Moeed 1975). The use of web-sourced photographs has recently been used to explore the diets of birds (Naude et al. 2019; Panter and Amar 2021). This method may suffer from bias, such as being photos more likely to be taken along roadsides, in open habitats, or in lower vegetation levels, but it can provide insight into a time- and cost-effective manner (Berryman and Kirwan 2021; Panter and Amar 2022). Our compilation of natural food sources derived from media associated with records from eastern North America (Suppl. material 3) suggests European Goldfinches may prefer the seeds of plant species not native to this region, but indigenous to their native range.

European Goldfinches are nearly entirely granivorous, specialising in the seeds of composites (Asteraceae) in their native range, strongly favouring thistles, burdocks, knapweeds, dandelions, and ragworts (*Senecio* spp.) (Newton 1967; Newton 1972 Cramp and Perrins 1994). Half of the plant taxa noted in our media review were composites, including all the taxa listed above, except for *Senecio* spp. All non-native taxa we identified except the grass *Bromus inermis* have been reported as food items by European Goldfinches in their native range (Newton 1967; Newton 1972; Cramp and Perrins 1994). A reliance on introduced Eurasian plants is a pattern noted in other regions where European Goldfinches have become established (Middleton 1970; Campbell 1972; Dias 2000). European Goldfinches that were previously established in North America in the New York region reportedly fed on burdocks, thistles, grasses, various garden composites, grasses, sweetgum, and larch (*Larix* spp.) (Elliott 1968), comparable to our findings.

There are many records of European Goldfinches at feeding stations. Many – especially those of multiple birds – are from feeders adjacent to appropriate habitats, such as parks or vacant land, including natural areas with known populations of European Goldfinches. Flocks of European Goldfinches, including juveniles, feeding on natural food sources much of the year suggest that while this species will utilise feeders, they readily adapt to and make use of widely available natural food sources and do not seem likely to be dependent on human provision of food.

Potential introduction pathway

We believe there is substantial evidence that the main source of the European Goldfinches in the western Great Lakes region was a dealer located in McHenry County, Illinois, ~ 80 km northwest of the city of Chicago (Illinois Secretary of State 2022).

This company was the largest importer of European Goldfinches into the U.S. for the years 2000–2014, imported many other cage birds (Eskew et al. 2019) and was the only company with a direct connection to this region. In April 1998, there was a report of a European Goldfinch from rural Walworth County, Wisconsin at a home < 10 km from the McHenry County address of the Illinois importer (Frank 1998). Between 2001 and 2004, there were also records of Common Chaffinches (*Fringilla coelebs*), Eurasian Blue Tits (*Cyanistes caeruleus*) and Great Tits (*Parus major*) in McHenry and Walworth counties and in nearby Racine County, Wisconsin; these and other cage-bird species were generally found < 200 km from the importer's location (David 2002; David 2004; Craves 2008). In her report of nesting Great Tits in McHenry County in 2003, Fiske (2004) suggested that the source of the birds was the McHenry County bird importer either accidentally or intentionally releasing exotic birds.

The majority of European Goldfinches imported into the U.S. from 2000–2005 were from Russia; all these birds were imported by the Illinois company. The country of origin listed in import records may not have been where wild-caught birds were actually collected, but rather the location from where birds harvested across a wider area are consolidated and exported (Eskew et al. 2020; Sinclair et al. 2021). It seems likely that many of the European Goldfinches imported by the Illinois company prior to 2006 were collected somewhere in eastern Europe and central Asia and perhaps from multiple locations throughout these regions.

Potential impacts

Thus far, most non-native bird species have failed to develop permanent populations in their new environments (Zenni and Nuñez 2013; Aagaard and Lockwood 2016). Those species which have become successfully established have interacted with many other taxa, with varying impacts on the recipient ecosystems (Blackburn et al. 2009). For birds, the most important impacts include predation; competition for resources, including food and nest sites; hybridisation; interaction with other non-native species, usually the spread of invasive plants via frugivory (Baker et al. 2014; Evans et al. 2016); and disease transmission (Springborn et al. 2014; Martin-Albarracin et al. 2015). Despite this potential for disruption, relatively few introduced bird species, particularly songbirds, have had severe impacts, especially outside of island settings (Bauer and Woog 2011; Strubbe et al. 2011; Baker et al. 2014).

Our data offer limited insight into potential impacts of European Goldfinches on native ecosystems. European Goldfinches are not predatory and they appear to be compatible with native songbirds. Comments included with many records indicated European Goldfinches were only occasionally aggressive towards other birds and were more often described associating with other finches, especially American Goldfinches (*Spinus tristis*). European Goldfinches are not cavity nesters and are unlikely to compete for nesting sites.

The primary natural food sources we documented being used by European Goldfinches in eastern North America are common weedy species, such as burdocks, teasels, and various thistles which are considered invasive in North America (EDDMapS

2022). Given the large variety of widespread, abundant plants suitable for European Goldfinches and native granivorous birds, it seems doubtful that competition for food resources could be problematic. Studies of European Goldfinches and related granivores indicate they are seed predators with few viable seeds being passed through their digestive tracts (von Mariluan 1895; Roessler 1936; McCallum and Kelly 1990; Heleno et al. 2011). European Goldfinches are not frugivorous and, thus, highly unlikely to disperse fleshy-fruited non-native plants. Dispersal of troublesome plants is presumably minimal, but data on foraging ecology are needed to assess unforeseen biotic interactions.

Hybridisation is considered a potential threat introduced birds may impose on native species (Baker et al. 2014). While European Goldfinches are frequently crossed with other finches in captivity, these hybrids are apparently nearly always sterile and wild hybrids are rare (Hinde 1956a, b; McCarthy 2006), suggesting the potential for negative impacts is low. The asynchrony in the breeding cycles of American and European Goldfinches may reduce the opportunity for hybridisation between these species; in eastern North America, American Goldfinches do not begin nesting until late June with a peak in the second half of July (Nickell 1951; Middleton 1978).

Our data shed little light on the potential role of European Goldfinches as reservoirs of disease or pathogens. There were no comments in the over 7000 records we compiled nor any images in the media we reviewed suggesting a sick bird, which might indicate infection with West Nile virus or *Mycoplasma gallisepticum*, the bacteria that cause conjunctivitis in House Finches and related Fringillids (Farmer et al. 2005). Pathogen screening and surveillance studies are needed to determine any disease risks posed by European Goldfinches.

In other countries where they have become established, European Goldfinches are not considered a major threat. They are not listed as an invasive species in Bermuda (Bermuda Department Environment and Natural Resources 2022) or the Azores (Marchante et al. 2020) and they are not included on the New Zealand Pest Register (Biosecurity New Zealand/Tiakitanga Pūtaiao Aotearoa 2022). In Australia, they are considered a "low interest" exotic species (DCCEEW 2007). Uruguay lists them as an invasive species of medium priority undergoing risk assessment (Aber et al. 2012) with no data on impacts (Aber et al. 2014).

Conclusions

Our data demonstrate that European Goldfinches are currently resident in the western Great Lakes region of North America. They have been breeding in an area between Milwaukee, Wisconsin and Chicago, Illinois continuously since 2003 and are now present in numbers that have established them as part of the local avifauna. Despite an earlier article published in the continent's journal of ornithological record drawing attention to this nascent population (Craves 2008), interest by birders and researchers has been limited. Thus, we lack high-quality, standardised datasets to allow us to rigorously and accurately interpret the history of these birds in the region. Nor do we have

information on many aspects of their ecology, such as seasonal movements, foraging ecology, clutch size, number of broods, or nesting success.

The lack of comprehensive data on a non-native bird species is not unique to European Goldfinches; insufficient knowledge is a common theme in literature (e.g. Blackburn et al. (2015)). Full understanding of the dynamics of non-native species successes and failures would benefit greatly from a change in the mindset of the birding community, who may disregard non-native species they encounter. The large and active birding community is ideally positioned to provide prompt detection of non-native bird species, a crucial phase in the establishment process for assessing and mitigating impacts. Yet, it is during these early stages that non-native birds are most likely to be ignored, as birders are discouraged from counting species that have not been present in a self-sustaining population for at least 15 years (American Birding Association 2020).

With the pet trade now the main source of avian introductions, even presumed escaped cage birds should not be ignored. In mid-2022, eBird initiated changes which encourage the reporting of all non-captive species, distinguish amongst several categories of exotic status, displaying them on range maps and will eventually segregate these species on user life lists (Team eBird 2022). We hope these developments spur a change in birder culture, reducing the current bias and offering a clearer picture of introduced bird source localities, founding numbers, and population growth. This seems especially urgent, given that several other non-native species we believe originated from the same source as the European Goldfinches are still being reported in the western Great Lakes region. Small numbers of Great Tits, a cavity-nesting species with potentially greater ecological impact, are successfully nesting in Wisconsin (https://ebird.org/atlaswi/map/gretit1), while much less easily recognised species such as Common Chaffinch or European Greenfinch (*Chloris chloris*) may be gaining a foothold largely unmonitored.

Although they have been present in the western Great Lakes region for at least 20 years and have years of breeding success, more detailed research is needed on European Goldfinches to fully assess their potentially increasing population and distribution, understand their basic ecology, and thoroughly evaluate their potential for range expansion and impacts on native species and ecosystems. The data we present here provide a foundation to build upon and an outline for further studies.

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Supplementary material 1

Records of European Goldfinches in North America, 2001–2021, by state/province with county totals. Records represent observations, not individual birds. Regions included in the western Great Lakes region are in bold

Authors: Julie A. Craves, Nicholas M. Anich

Data type: Spreadsheet file (.xls)

Explanation note: The data summarized here from eBird (https://ebird.org/data/download), Project FeederWatch (https://feederwatch.org/explore/raw-dataset-requests), iNaturalist (https://www.inaturalist.org/observations/export), and the United States Fish and Wildlife Service (USFWS) Law Enforcement Management Information System (LEMIS) database (https://zenodo.org/record/3565869) are available for download from each of those sites. Data summarized here that originated from social media, photo sharing sites, or those records provided directly to the authors from individuals are not publicly available due to privacy restrictions. Please contact the corresponding author for inquiries [29 kb].

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Link: https://doi.org/10.3897/neobiota.81.97736.suppl1

Supplementary material 2

Mapped locations of confirmed breeding European Goldfinches in the western Great Lakes region, 2001–2021

Author: Julie A. Craves

Data type: Google Earth compressed keyhole markup language file (.kmz)

Explanation note: Single points on the map may represent many records assigned to a single location (e.g., a "hotspot" in eBird representing a larger area, observations of a pair of birds over several days). Clicking on a point will display any multiple records. Clicking on individual records will show the breeding code (see text for descriptions) and year of record; ID code is for author reference. Light blue points indicate imprecise coordinates placed at a town center. County names and boundaries are in yellow. Counties that do not contain points are those that had breeding records coded as Probable, not confirmed. Counties recording pairs of birds in 2006 only are not included (see text) [34 kb].

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Link: https://doi.org/10.3897/neobiota.81.97736.suppl2

Supplementary material 3

Natural food sources of European Goldfinches in eastern North America

Author: Julie A. Craves

Data type: Document file (.docx)

Explanation note: Compilation is based on photographic records of birds actively foraging of plant material, not birds merely perched on food plants. Records that included multiple photos of a foraging bird were counted only once. Bold indicates a taxa not native to North America. Taxonomy follows the World Checklist of Vascular Plants version 8 (WCVP 2022), nativity data from U.S. Department of Agriculture's PLANTS Database (USDA, NCRS 2022). Abbreviations: CT = Connecticut, GA = Georgia, IL = Illinois, MA = Massachusetts, NY = New York, OH = Ohio, ON = Ontario, QC = Quebec, VA = Virginia, WI = Wisconsin [15 kb].

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